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ABSTRACT:

A method of irradiating plants by radiation suitable for photosynthesis. Of the radiation power in the wavelength range of 250 nm to 780 nm, 90 % is emitted in the wavelength range of 400 to 780 nm and 5 to 10 % in the wavelength range of 350 to 450 nm.

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(54) **Method of irradiating plants.**

(57) A method of irradiating plants by radiation suitable for photosynthesis. Of the radiation power in the wavelength range of 250 nm to 780 nm, 90 % is emitted in the wavelength range of 400 to 780 nm and 5 to 10 % in the wavelength range of 350 to 450 nm.

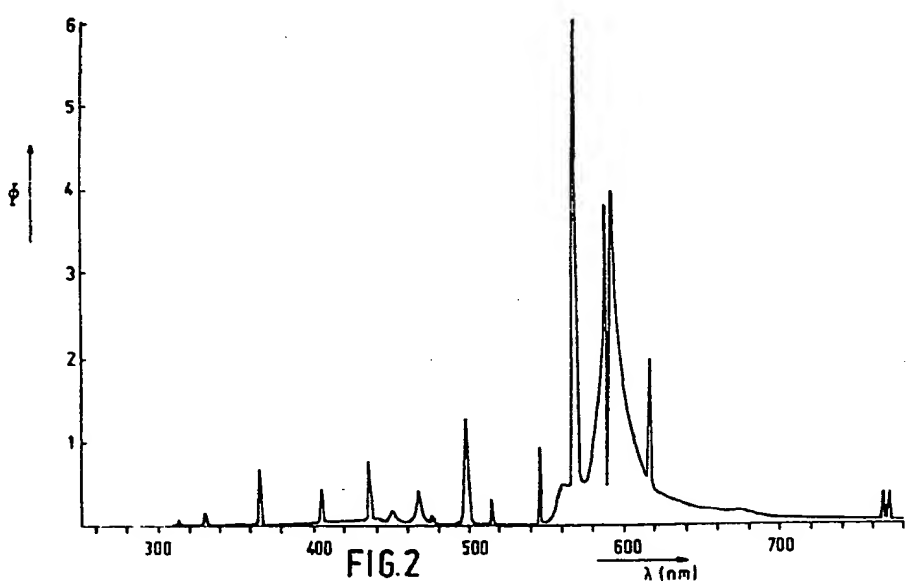

FIG.2

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Method of irradiating plants.

The invention relates to a method of irradiating plants with radiation which is suitable for photosynthesis and is produced in an electrical discharge lamp with a radiation power of V lying in a wavelength range of 250 nm to 780 nm, of which a proportion A lies in a wavelength range of 400 nm to 780 nm, A being at least 90 % of V.

The method mentioned in the opening paragraph is frequently used inter alia in the growth of plants, such as vegetables, pot plants and cut flowers. Irradiation then mostly takes place in addition to daylight in the form of an increase of the luminous intensity. Lengthening of the time with respect to the daylight duration available can also be realized with this method. Especially in areas in which during a part of the year only short daylight lengths occur and also in areas in which daylight periods of low intensity occur for a longer period of time, the aforementioned irradiation processes are frequently used. A further possibility is that the irradiation process is used as substitute for daylight irradiation.

Photosynthesis is of major importance for growth of plants. Radiation in the wavelength range of 400 to 780 nm is particularly favourable for photosynthesis. For a satisfactory photosynthesis, besides a regular long irradiation a high radiation level is required, which level depends upon the type of plants which is subjected to the irradiation. Besides, irradiation with visible light is of importance for the morphology of plants. Morphology is determined to a great extent by the spectral distribution of radiation and radiation having wavelengths smaller than 550 nm is then also of importance. The spectrum generated by the sun has such a composition that it is conducive to both photosynthesis and plant morphology.

With irradiation by means of spectra emitted by electrical discharge lamps, many kinds of methods are necessarily in use, inter alia depending upon the type of plant, but also determined to great extent by the type of lamp used. Lamps of different types have spectra which are greatly different from each other. This necessitates the choice of a method for irradiation, in which either the radiation of the spectrum originating from the lamp used is replenished with radiation of another source to avoid a deficiency of radiation in a specific wavelength range or the effectiveness of the radiation for the process of photosynthesis is reduced. Mostly, daylight is used as an addition. However, under conditions of limited daylight length or limited daylight intensity, this form of radiation addition is insufficient to guarantee a satisfactory influencing of the plant morphology. For certain plants, a growth-inhibiting treatment must then be carried out, which, however, in practice mostly leads nevertheless to an unacceptable plant morphology, inter alia due to the hardly predictable character of the daylight intensity. All this is disadvantageous for efficiently growing plants. However, even in given circumstances it is necessary to carry out an irradiation by means of a combination of lamps in order to influence besides photosynthesis also plant morphology in an efficient manner. Such a method, however, can be used practically only for application in particular conditions because it is necessary for regularly growing plants that each plant intercepts during the irradiation light from both lamps in a correct intensity ratio. Therefore, stringent requirements are imposed on the installation of the lamps, as a result of which such a method becomes very expensive.

The invention has for its object to provide a measure with which it is possible to irradiate a great variety of plants, an efficient influencing of photosynthesis and plant morphology being guaranteed to a great extent under greatly different as well as alternating conditions.

For this purpose, the method of the kind mentioned in the opening paragraph is characterized in that the irradiation is carried out so that for a proportion B lying in a wavelength range of 350 nm to 450 nm the relation is satisfied that $5\ \% \leq \frac{B}{V} \leq 10\ \%$.

It has been found that such a comparatively small radiation contribution in a comparatively small part of the wavelength range, i.e. the blue part of the spectrum, is sufficient to influence in many plants the plant morphology so favourably that the process of photosynthesis activated by the radiation leads to well-formed plants. This offers the possibility of a comparatively simple and hence inexpensive process-controlled growth of plants, which is highly independent of daylight length and daylight intensity. Expensive measures with the use of two types of lamps can be omitted, while also risky steps of growth inhibition are superfluous.

For an efficient method, a high radiation efficiency of the lamp is of major importance. High-pressure sodium lamps generally have a radiation efficiency which is 250 mW/W or more and are thus particularly suitable to carry out a process for photosynthesis. Due to a small contribution in the spectral range of 350 nm to 450 nm, high-pressure sodium lamps are not particularly suitable for use in the method according to the invention. However, a method is particularly suitable, in which the radiation is produced in a high-pressure sodium discharge lamp, which is provided with a discharge vessel having a ceramic wall and containing besides sodium also mercury and xenon as a filling in such a manner that the sodium is present

in a quantity of at most 12 % by weight and at least 6 % by weight with respect to the whole mass of sodium and mercury and that at 300 K the xenon pressure is at least 26.7 kPa. It has been found that this combination of filling proportions permits of generating a spectrum by the high-pressure sodium lamp, in which a considerably increased contribution is obtained in the wavelength range lying between 350 nm and 450 nm simultaneously with a high radiation efficiency. In practice, this is achieved by producing a pressure of the sodium in the operating condition which corresponds to a wavelength difference $\Delta\lambda$ between maxima of flanks limiting a sodium self-absorption band at 590 nm, which lies between 6 nm and 4 nm. Of such a high-pressure sodium lamp, the luminous efficacy proves to have a value comparable with that of conventional high-pressure sodium lamps, in which Xe is used as starting gas (i.e. up to a filling pressure of 6.7 kPa). A further advantage of the method with the use of this lamp is that the colour rendition of the plants is improved. This permits of carrying out visual inspection of the irradiated plants during the irradiation.

The invention will now be described more fully with reference to a drawing, in which:

Figure 1 is a side elevation of a lamp according to the invention partly broken away,

Figure 2 shows a spectral distribution of the light emitted by the lamp shown in Figure 1,

Figure 3 shows the spectral distribution of light emitted by another lamp according to the invention, and

Figure 4 shows the spectal distribution of the light emitted by a lamp according to the prior art.

Of the lamp shown in Figure 1, reference numeral 1 denotes a discharge vessel having a ceramic wall and reference numeral 2 denotes an outer envelope, which encloses the discharge vessel and is provided at one end with a lamp cap 3. The discharge vessel is provided at both ends with electrodes 4, 5 each connected to a lead-through member 6 and 12, respectively. The lead-through member 6 is connected via a conductor 7 to a rigid current conductor 8, which is connected at one end to a first contact point (not shown) on the lamp cap 3. Another end of the rigid current conductor 8 is flanged and serves as supporting means within and on the outer envelope 2. The lead-through member 12 is connected via a Litze wire 13 to a rigid current conductor 9, which is connected at one end to a second contact point (not shown) on the lamp cap 3.

The discharge vessel 1 is provided with an aerial 20, which is electrically connected at one end to the conductor 7. Another end of the aerial 20 is connected to a bimetal element 21, which is secured to the rigid current conductor 8. In the inoperative condition of the lamp, the bimetal element 21 bears on the wall of the discharge vessel and thus the aerial also engages the wall of the discharge vessel. In the operative condition of the lamp, the bimetal element is heated by the radiation emitted by the discharge vessel in such a manner that the bimetal element bends away from the discharge vessel so that the aerial 20 is removed for the major part from the wall of the discharge vessel. The filling of the discharge vessel consisted of 26 mg of sodium and mercury in a weight ratio Na/Hg of 0.125 and xenon at a pressure of 40 kPa at about 300 K. The lamp shown has a nominal power of 400 W, an arc voltage of 100 V and an electrode gap of 90 mm.

The spectrum of the light generated by the lamp described is shown in Figure 2. The wavelength difference $\Delta\lambda$ is 4.8 nm. In Figure 2, the wavelength is plotted in nm on the abscissa and the radiation power Φ (the radiation energy current) is plotted in a relative measure on the ordinate. For comparison, Figure 3 shows a spectrum of a lamp, in whose filling the Na/Hg weight ratio was 0.075. In this case, the wavelength difference $\Delta\lambda$ is 4.2 nm. Finally, Figure 4 shows the spectrum of a conventional lamp containing as filling Na and Hg in a weight ratio Na/Hg of 0.225 and xenon at a filling pressure of 3.6 kPa. The wavelength difference $\Delta\lambda$ in this lamp is 7.4 nm.

Table I indicates for each spectrum contributions in the radiation power in different wavelength ranges in % of the overall radiation power between 250 nm and 780 nm. Further, the radiation efficiency and the luminous efficacy are indicated.

TABLE I

Spectrum		Fig. 4	Fig. 2	Fig. 3
Luminous efficacy (lm/W)		117	123	113
Relative contribution to the radiation power %	250-780 nm	100	100	100
	400-780 nm	96	95	93.7
	500-780 nm	86.5	85.2	83.7
	350-450 nm	3.9	5.7	7.8
Radiation efficiency (mW/W)		324	299	285

The method according to the invention has been tested in practice, as described further. By the spectrum of the kind shown in Figure 2, different kinds of plants are irradiated and grown in a room sealed from daylight. The daylight length was 16 hours with an irradiation intensity in the wavelength range lying between 400 nm and 780 nm of 33.4 W/m². For comparison, the same kinds of plants have been grown with irradiation originating from a conventional high-pressure sodium lamp, which generates a spectrum as shown in Figure 4 in the same conditions, but with a radiation intensity of 37.3 W/m².

Table II indicates results of the plants thus grown. The results are indicated in crop weight per plant, expressed in gms.

TABLE II

Irradiation intensity (W/m²)	33.4		37.3	
Growth duration (week)	1	2	1	2
Cucumber	41.6	-	35.0	-
Tomato	9.6	28.9	7.9	23.5
Lettuce	23.2	39.9	23.3	39.3

It appears from Table II that a higher radiation intensity in the wavelength range interesting for photosynthesis does not lead to a correspondingly increased plant growth. Visual inspection of the plants grown showed that the plants grown by means of the method according to the invention were more intensely coloured than the plants grown for comparison. In the tomato, it further appeared that ageing of the leaves in the plant grown for comparison was considerably stronger than in the plant irradiated in accordance with the invention.

In a further experiment, cauliflower is grown for a week on the one hand irradiated by a spectrum according to Figure 2 having an intensity of 8.4 W/m² and on the other hand irradiated by a spectrum according to Figure 4 having an intensity of 9.4 W/m². The crop weight measured per plant in gms was for the plant irradiated by the spectrum according to Figure 2 2.30 gms and for the other plant 1.03 gms. Moreover, in the case of the latter plant, not only a smaller growth, but also considerable yellowing phenomena of the leaves occurred, which indicates a deficiency of blue radiation. The plant which was irradiated by a spectrum according to Figure 2, i.e. with the use of the method in accordance with the invention, substantially did not exhibit yellowing phenomena.

Claims

1. A method of irradiating plants with radiation which is suitable for photosynthesis and is produced in an electrical discharge lamp with a radiation power of V lying in a wavelength range of 250 nm to 780 nm, of which a proportion A lies in a wavelength range of 400 nm to 780 nm, A being at least 90 % of V, characterized in that the irradiation is carried out so that for a proportion B lying in a wavelength range of 350 nm to 450 nm the relation is satisfied that $5\ \% \leq \frac{B}{V} \leq 10\ \%$.

2. A method as claimed in Claim 1, characterized in that the radiation is produced in a high-pressure sodium discharge lamp, which is provided with a discharge vessel having a ceramic wall and containing besides sodium also mercury and xenon as a filling in such a manner that the sodium is present in a quantity of at most 12 % by weight and at least 6 % by weight with respect to the whole mass of sodium and mercury and that at 300 K the xenon pressure is at least (200 torr) 26.7 kPa.

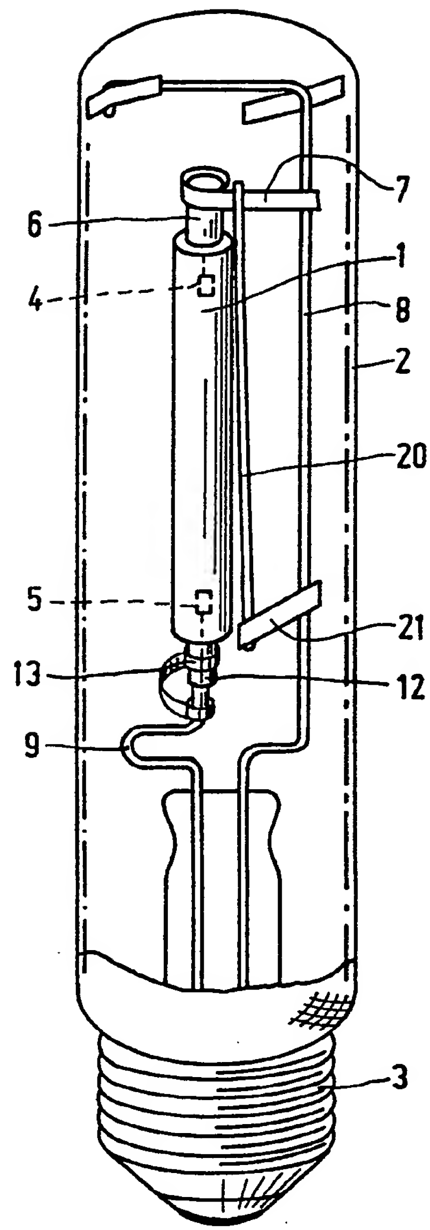

FIG.1

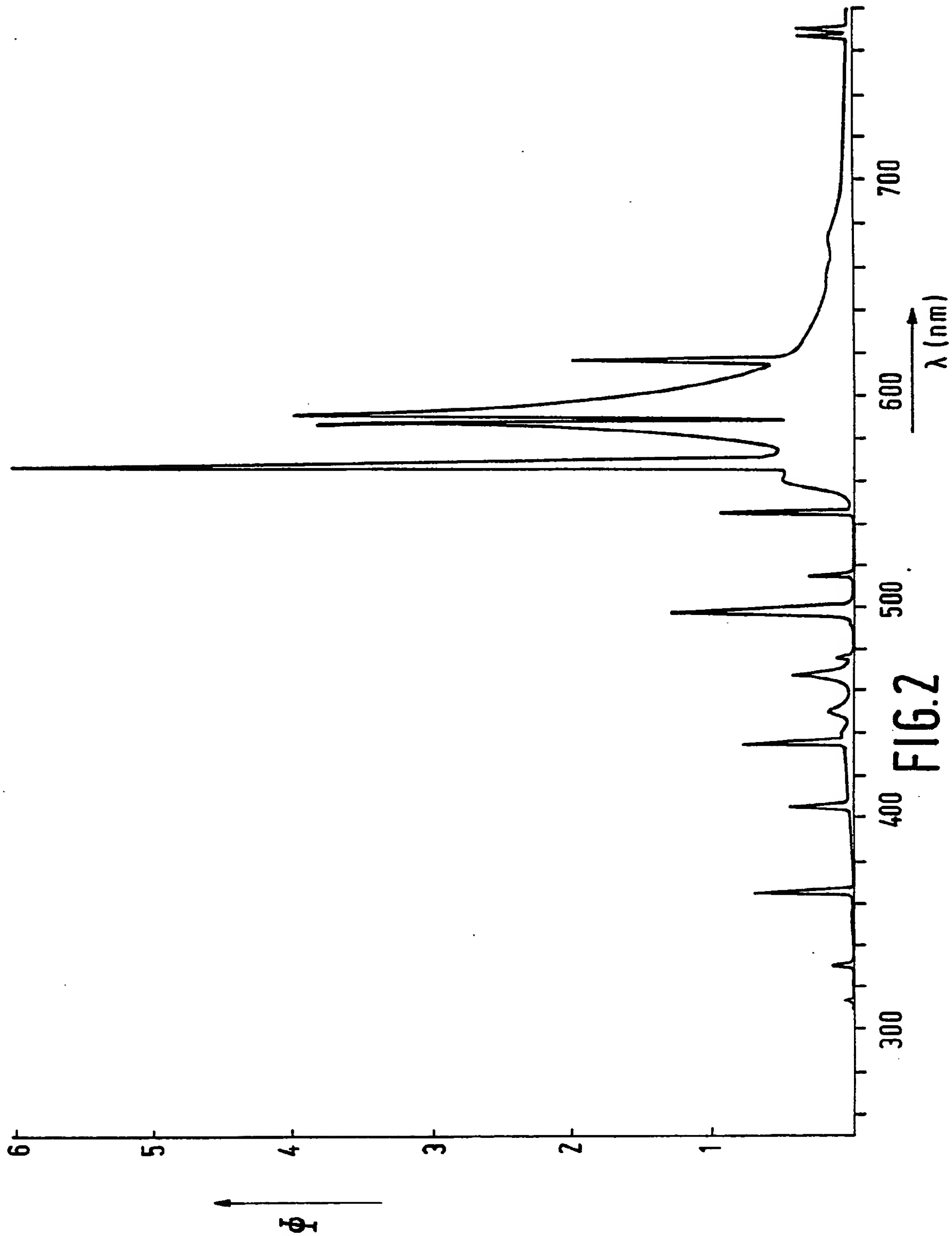

FIG.2

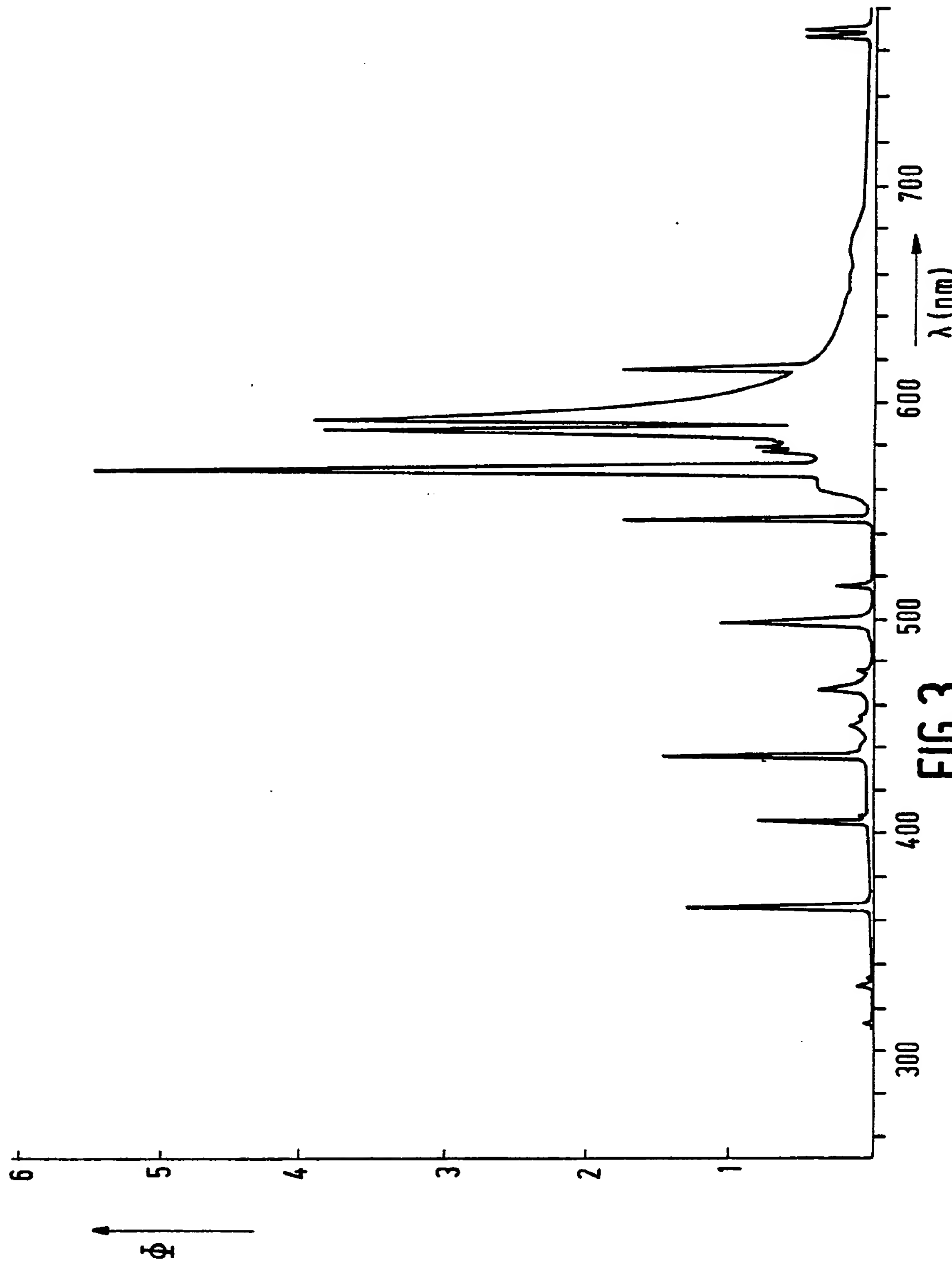

FIG.3

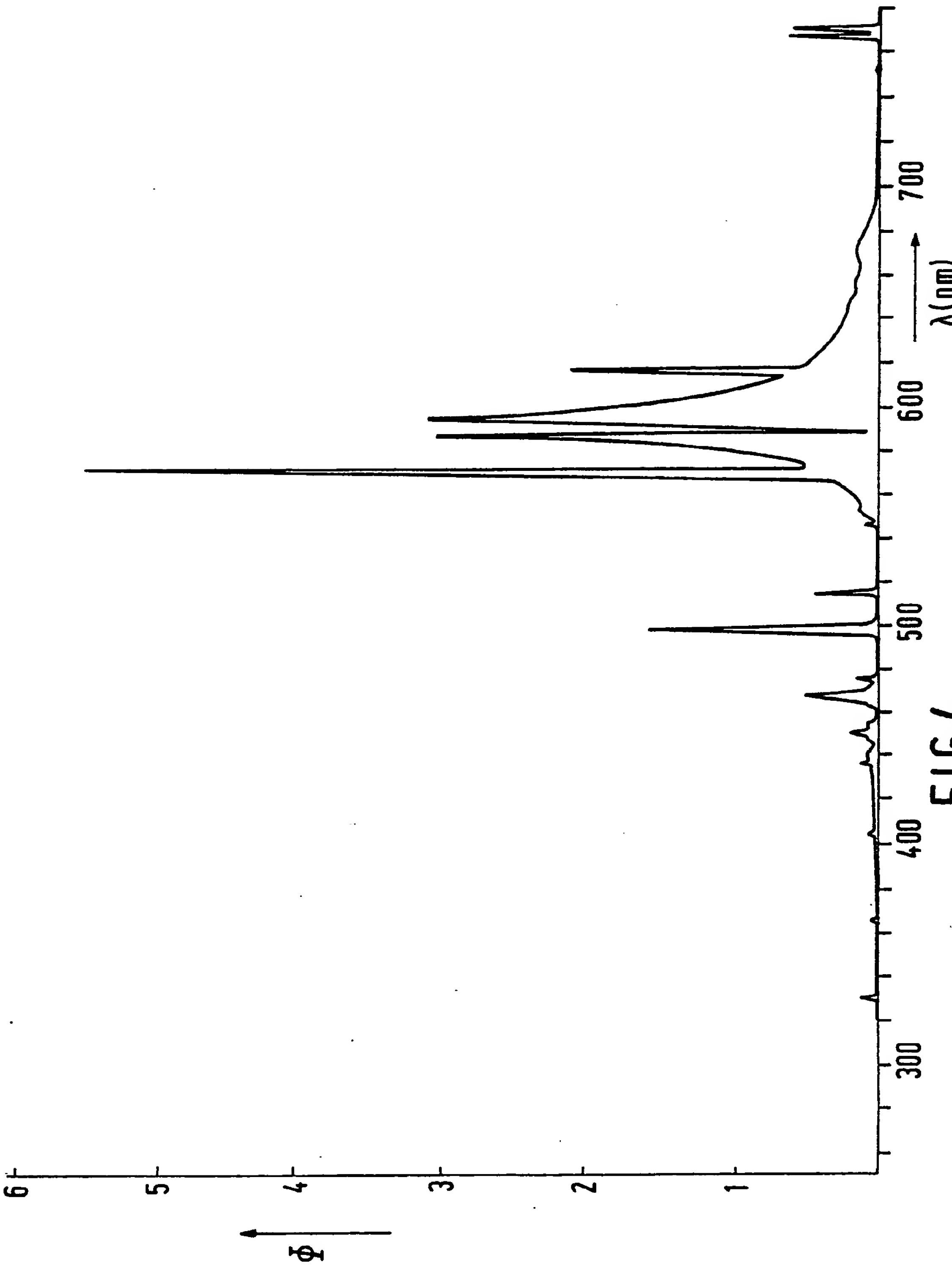

FIG.4

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EUROPEAN SEARCH REPORT

Application Number

EP 89 20 2266

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 387 510 (PHILIPS) * Page 5, line 19 - page 8, line 23; figures 1,2 * ---	1,2	
A	IEE PROCEEDINGS, vol. 128, no. 6A, September 1981, pages 415-441, Old Woking, Surrey, GB; J.A.J.M. van Vliet et al.: "High-pressure sodium discharge lamps" * Paragraphs 3,5,6 * ---	1,2	
A	JOURNAL OF IES, vol. 11, no. 4, July 1982, pages 231-240, New York, US; K. OTANI et al.: "A high pressure sodium lamp with improved color rendition" * Whole article * ---	1,2	
A	J.E. KAUFMAN: Ies Lighting Handbook, Application Volume, 1981, pages 19-22,19-23, Illuminating Engineering Society of North America, New York, US; * Pages 19-22,19-23 * -----	1,2	TECHNICAL FIELDS SEARCHED (Int. Cl.5)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	01-12-1989	SARNEEL A.P.T.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number

EP 89 20 2266

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 387 510 (PHILIPS) * Page 5, line 19 - page 8, line 23; figures 1,2 *	1,2	H 01 J 61/82 H 01 J 61/22
A	IEE PROCEEDINGS, vol. 128, no. 6A, September 1981, pages 415-441, Old Woking, Surrey, GB; J.A.J.M. van Vliet et al.: "High-pressure sodium discharge lamps" * Paragraphs 3,5,6 *	1,2	
A	JOURNAL OF IES, vol. 11, no. 4, July 1982, pages 231-240, New York, US; K. OTANI et al.: "A high pressure sodium lamp with improved color rendition" * Whole article *	1,2	
A	J.E. KAUFMAN: Ies Lighting Handbook, Application Volume, 1981, pages 19-22,19-23, Illuminating Engineering Society of North America, New York, US; * Pages 19-22,19-23 *	1,2	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H 01 J 61/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	01-12-1989	SARNEEL A.P.T.

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